3468A Multimeter

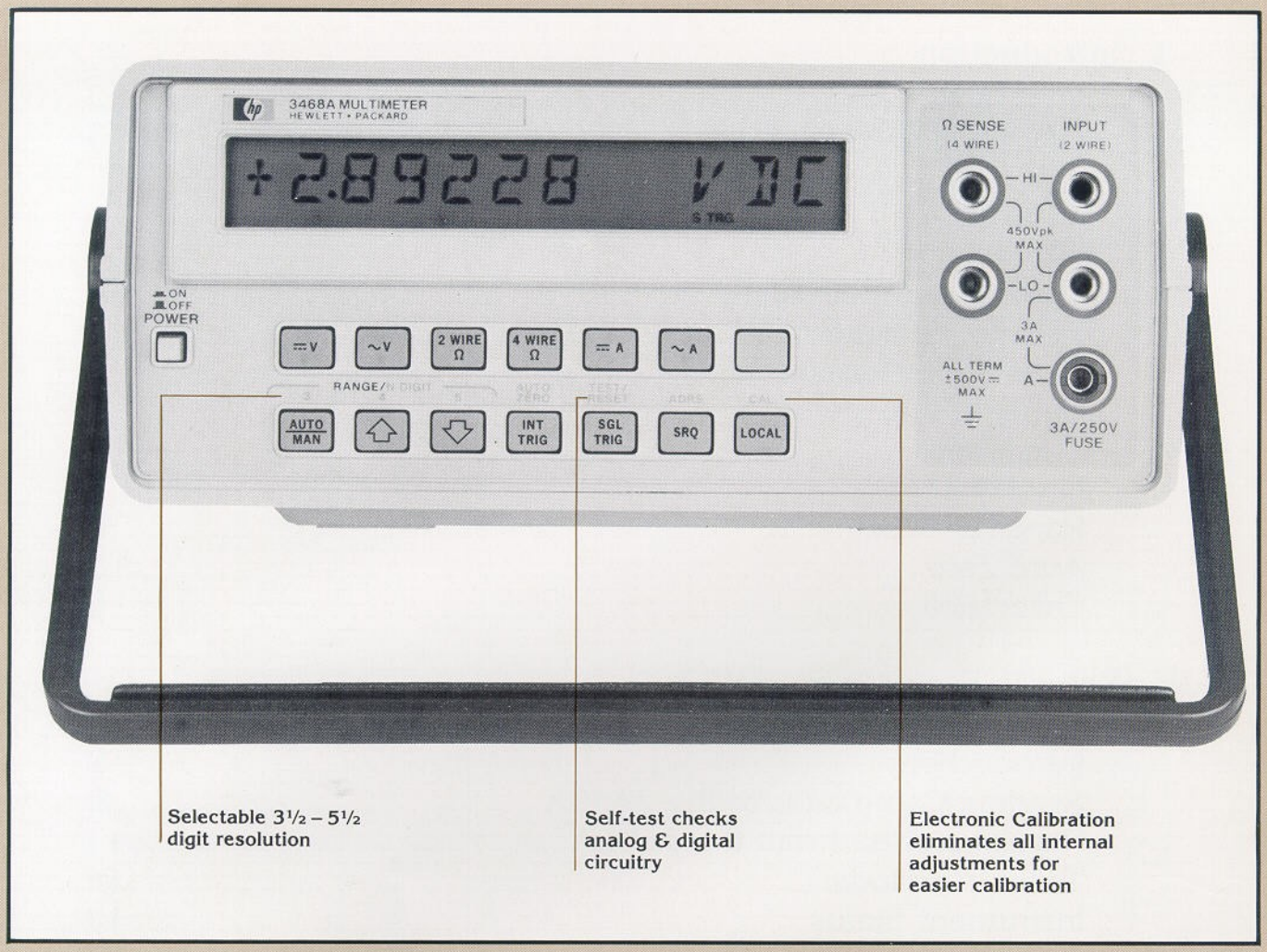
Using the 3468A

Product Note 3468A-1

HEWLETT PACKARD

Contents

3468A Multimeter



Selectable 3½ – 5½ digit resolution

Self-test checks analog & digital circuitry

Electronic Calibration eliminates all internal adjustments for easier calibration

Introduction

Overview

The HP 3468A Multimeter brings the power and flexibility of automated measurements to your bench with the Hewlett-Packard Interface Loop (HP-IL)*. HP-IL provides a simple means of interfacing instruments and controllers for bench automation or portable field testing. The 3468A is fully programmable via this 2-wire serial interface using the HP 41C/CV handheld controllers or the HP 85A computer. Automating bench measurements permits easy storage and analysis of data from your experiment. You can convert measurements into results by linearizing transducers or performing statistical analysis on data.

The 3468A provides selectable 3½ – 5½ digit resolution for measuring dc volts, RMS ac volts, 2-and 4-wire ohms, and dc and ac current. The 3468A can make precise dc and ac voltage measurements with 1 μV sensitivity, measure resistance to 30 MΩ, and accurately perform RMS acV tests to 100 kHz. Optional rechargeable batteries provide portability.

Selecting the number of digits displayed gives you the right combination of resolution, accuracy, and noise rejection for your application. The 3468A's autoranging allows fast measurements over a wide range of signals. The alphanumeric liquid crystal display provides measurement units and user messages as part of the reading for easy-to-read, unambiguous answers.

Calibration is simplified by eliminating all internal adjustments. Just connect the calibration standard to the 3468A and store calibration constants in nonvolatile memory. You can use the front panel keys to manually store the constants or calibrate automatically with HP-IL. Complete calibration without removing the covers lowers your cost of ownership.

*HP-IL (Hewlett-Packard Interface Loop): HP's new serial interface designed for small, low cost battery operable systems.

Operating Characteristics

The operating characteristics of the 3468A are given in Table 1. You will probably find that this table answers most of your questions about the capabilities of the 3468A without reading several pages of specifications. The complete Table of Specifications for the 3468A is given in Section IV.

Table 1. 3468A Operating Characteristics

Functions	dcV, RMS acV, 2-, 4-wire ohms, dc current, RMS ac current	**2- and 4-Wire Ohms**	
Resolution	3½ – 5½ digits	Ranges	300 Ω – 30 MΩ full scale
Interface	HP-IL (standard)	Sensitivity	1 mΩ on 300 Ω range
		Accuracy (1 yr.)	0.016%
DC Voltage		**DC Current**	
Ranges	300 mV – 300 V full scale	Range	3.0 A
Sensitivity	1 μV on 300mV range	Sensitivity	10 μA
Accuracy (1 yr.)	0.018%	Accuracy (1 yr.)	0.17%
RMS AC Voltage		**RMS AC Current**	
Ranges	300 mV – 300 V full scale	Ranges	300 mA – 3.0 A full scale
Sensitivity	1 μV on 300 mV range	Sensitivity	1 μA on 300 mA range
Accuracy (1 yr.)	0.26%	Accuracy (1 yr.)	1.0%
Freq. Range	20 Hz – 100 kHz	Freq. Range	20 Hz – 20 kHz

Operation

Introduction

This section describes how measurements are easily made with the 3468A. Operating information is organized by subject, as listed below, to provide answers to most questions about the 3468A. Each subject also contains the HP-IL command codes to implement that subject. Detailed HP-IL programming information and example programs for the HP 41C/CV are provided in Section III. For additional information regarding 3468A operation or service, refer to the 3468A Operator's Manual (HP Part No. 03468-90000) or 3468A Service Manual (HP Part No. 03468-90001).

Turn-on and Self-Test

At turn-on, the 3468A performs a self-test of its circuitry.

The 3468A is then configured for:

Function:	DC Volts
Ranging:	Autorange
Display:	5½ Digits
Trigger:	Internal Trigger
Auto Zero:	On

Self-Test 

The Self-Test function that occurs at turn-on may also be used at any time to verify proper operation of the 3468A. A self-test will first turn on all the elements of the liquid crystal display (LCD).

The self-test then checks the digital and A/D converter circuitry, providing the same "SELF-TEST" display as during turn-on. If any part of the self-test should fail, an error message on the display will indicate which part of the instrument needs attention. For more information regarding self-test messages, please refer to the 3468A Service Manual.

Voltage Measurements

You can use the 3468A to measure dc and RMS ac voltage with up to 1 μV sensitivity. The 3468A provides noise rejection for quiet readings during dc voltage measurements in the 4½ and 5½ digit display modes. Considerations for optimizing accuracy, resolution and noise rejection are discussed in the Display Section.

DC Voltage Measurements 

DC voltages measured on the 3468A are simple and straightforward. Press the DC Voltage key and either select the appropriate range or allow the multimeter to autorange. Read the display directly (no multiplying the reading by the range, etc.) for the measured voltage.

HP-IL **COMMAND**

F1 Selects the DC Volts mode

AC RMS Voltge Measurements

~V

Like dc voltage measurements, ac measurements are very straightforward. Press the AC Voltage key and appropriate range key(s). The display is read directly for the measured voltage.

The 3468A uses a True RMS ac to dc converter for ac voltage and current measurements. Unlike an average ac detector, the True RMS ac converter allows accurate measurement of voltages that are noisy, distorted, or non-sinusoidal, such as square and triangle waves, sawtooths and pulse trains.

HP-IL **COMMAND**
F2 Selects the AC Volts mode

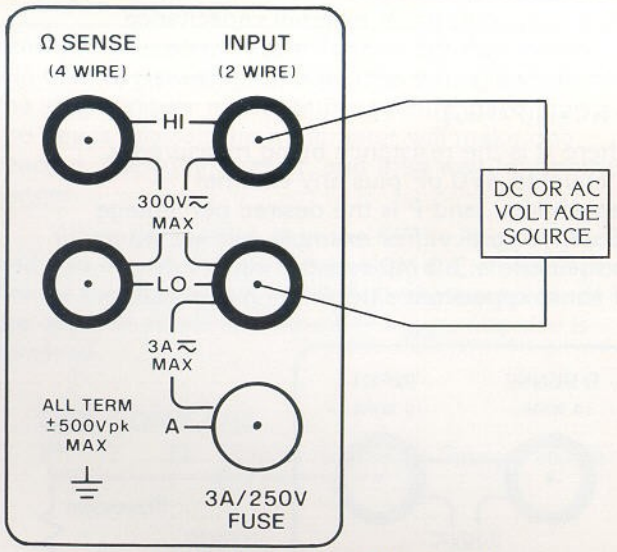


Figure 1. Voltage Measurements

Resistance Measurements

The 3468A can measure resistance to 30 MΩ with up to 1 mΩ sensitivity. Resistance measurements may be made in either 2-wire or 4-wire (Kelvin) ohms configuration. Resistance in excess of 30 MΩ may be measured using the extended ohms mode, under remote control only (see "Example Application Programs" in Section III).

How Resistance is Measured

The 3468A measures resistance by sourcing a known, precise current through the unknown resistance. A dc voltage measurement is made across the resistance, and the value of resistance is calculated and displayed by the 3468A. Figure 2 shows the connections for both 2-wire and 4-wire ohms measurements.

2-Wire Ohms

2 WIRE Ω

The 2-wire ohms mode is used most commonly for convenience or when the resistance of the test leads is not critical. Inaccurate results may be obtained when using the 2-wire ohms mode if the resistance of the test leads is large relative to that of the unknown. This is because the 3468A measures the total resistance between its terminals, including the test lead resistance. Examples of this include measurements with long test leads or measurements of very low resistance (a few ohms or less).

HP-IL **COMMAND**
F3 Selects 2-Wire Ohms mode

4-Wire Ohms

4 WIRE Ω

The use of 4-wire ohms measurements eliminates errors caused by test lead resistance. The current through the unknown is constant regardless of lead resistance, and the 3468A measures only the voltage across the unknown resistance, not across the combination of unknown plus test leads. Four-wire resistance measurements are required for highest accuracy or when long leads are used.

HP-IL **COMMAND**
F4 Selects 4-Wire Ohms mode

Other Considerations

1. Always use the shortest possible test leads. This is important on the lower ranges to minimize errors due to lead resistance (2-wire ohms mode), and on the higher ranges to minimize noise pickup.
2. The current flowing through the unknown resistance will cause some self-heating of the unknown. The power dissipated will be equal to I^2R; thus, low values of current minimize self-heating and any resistance changes caused by the self-heating. If desired, you can lower the current by upranging the 3468A (see Table 2). However, this will also decrease the resolution of your measurement.

Table 2. Currents Through Unknown Resistance

Resistance Range	Current Through Unknown
300 Ω	1 mA
3 kΩ	1 mA
30 kΩ	100 μA
300 kΩ	10 μA
3 MΩ	1 μA
30 MΩ	100 nA

3. Additional settling time may be required when using the higher ohms ranges under program control. This is important if there is

more than 200 pF of external capacitance in parallel with the unknown resistance. Theorectically, the settling time necessary is:

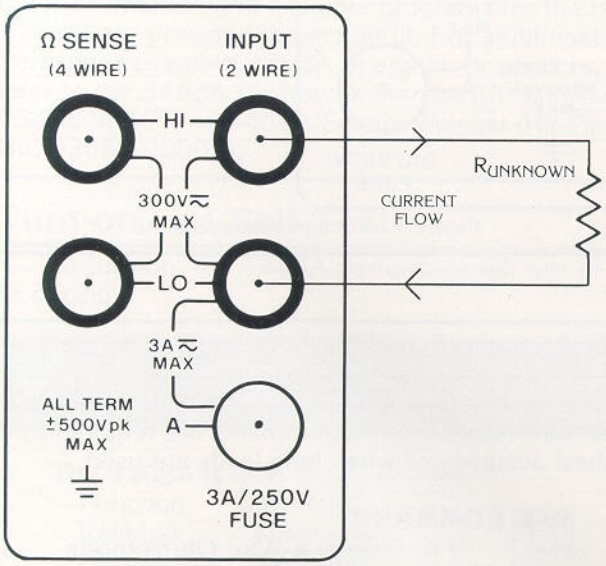
$-RC*\ln(P/100)$,

where R is the resistance being measured, C is equal to 470 pF plus any external capacitance, and P is the desired percentage of step accuracy. For example, say we want to measure a 3.0 MΩ resistor with 1200 pF of shunt capacitance (High-to-Lo terminals).

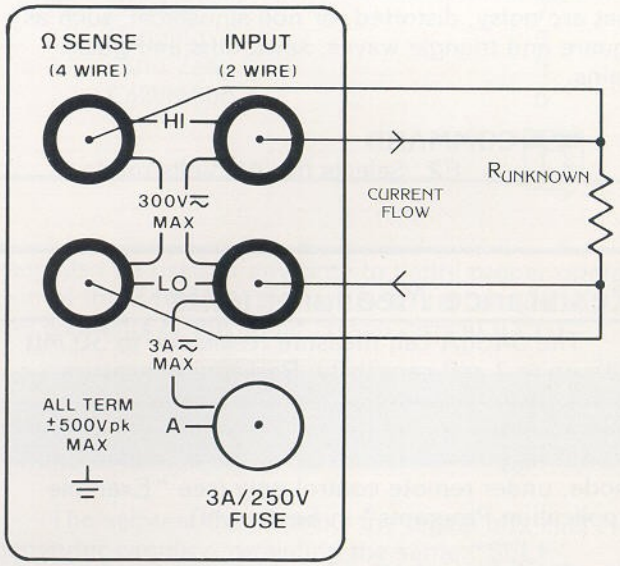
If a short was previously applied (short to 3.0 MΩ = step) and a .001% reading is desired, the settling time necessary is:

$-(3*10^{6})*(1200+470)*(10^{-12})$
$*(\ln(.001/100)) = 58$ msec

Since on the 3 MΩ range there is an internal delay of 20 msec, an additional delay of 38 to 40 msec should be allowed. The 30 MΩ range has an internal delay of 200 msec.



2-WIRE OHMS MEASUREMENT



4-WIRE OHMS MEASUREMENT

Figure 2. Resistance Measurements

Current Measurements

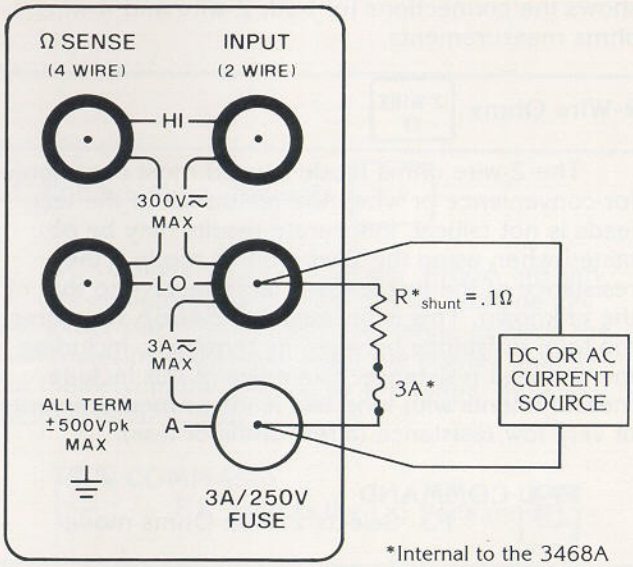
The 3468A can measure dc or True RMS ac currents up to 3 amps. The current function is protected by a 3 amp, 250V fuse. Figure 3 shows current measurement connections and the internal current shunt and fuse used in the 3468A. The unknown current flowing through the internal current shunt produces a voltage which the 3468A measures.

DC Current [⎓ A]

The DC Amps key puts the 3468A into the dc current measuring mode. DC current measurements are made on the 3 amp range.

AC Current [~ A]

Measuring ac current is identical to dc current except that the AC Amps key is used to select the measurement function. Measurements may be made on the 300mA or 3.0A range.



*Internal to the 3468A

Figure 3. Current Measurements

HP-IL COMMANDS

F5 Selects DC Current mode
F6 Selects AC Current mode

Triggering

Triggering is simply the process that causes the 3468A to take a reading.

Internal Trigger INT TRIG

In the internal trigger mode the 3468A triggers itself to take readings at the maximum possible rate. This mode is automatically selected at instrument turn-on and after performing self-test. A settling delay has been added before each A/D conversion in ac volts and ac current, and for the two highest ohms ranges to ensure accurate readings.

HP-IL **COMMAND**
T1 Selects the Internal Trigger mode

Single Trigger SGL TRIG

The single trigger mode allows you to manually trigger the multimeter from its front panel. The first time you press the Single Trigger key the 3468A will take one reading, display the results, and go to the single trigger mode. Subsequently, each time the key is pressed the multimeter will make one reading, display the result, and then wait for another trigger.

When the 3468A is in the Single Trigger mode and you change range or function, the left-hand portion of the display will blank (with the exception of the decimal point) until another trigger impulse is received.

HP-IL **COMMAND**
T2 Selects the Single Trigger mode

Display

The 3468A's display provides readings with selectable 3½ – 5½ digit resolution. Measurement units (VDC, VAC, KOHM, etc.) are displayed with the reading. Messages may also be displayed with the 12 character alphanumeric liquid crystal display (LCD).

Number of Displayed Digits

Selecting the number of digits displayed also controls the integration time of the 3468A's A/D converter. Thus, the number of digits displayed controls resolution, accuracy, noise rejection and measurement speed.

3

This puts the 3468A into the 3½ digit display mode. This mode has the fastest reading rate but the lowest resolution and no normal mode rejection. The integration time in this mode is 0.1 power line cycle.

4

This is the 4½ digit display mode. This mode provides 59 dB of normal mode rejection with an integration time of 1 power line cycle (16.66 msec at 60 Hz, 20 msec at 50 Hz).

5

The 5½ digit display mode provides the greatest resolution and noise rejection. In this mode, 10 readings are taken, each with 1 power line cycle integration time, and averaged together. This provides 80 dB of normal mode rejection.

Displayed Messages

The 3468A will display messages indicating the HP-IL address, user errors, self-test failures and calibration status (see 3468A's Operator's Manual). User generated messages of up to 12 alphanumeric characters may also be displayed using the "D2" HP-IL command. Examples could include status prompts such as "TEST PASSED" or readings in the desired units such as "257.8 DEG C". To display a message such as "NEXT TEST", simply send the following command to the 3468A: "D2 NEXT TEST".

HP-IL **COMMANDS**
N3 Selects 3½ digit display
N4 Selects 4½ digit display
N5 Selects 5½ digit display
D1 Selects normal readings display
D2 User generated message mode. (D2XXXXXXXXXXX places the message "XXXXXXXXXXX" on the display).

Ranging

The 3468A provides a choice of automatic or manual ranging on all functions.

The AUTO/MAN key alternates the 3468A between the autoranging and manual ranging modes. A display annunciator indicates when the 3468A is in the manual ranging mode.

The 3468A may be manually upranged or downranged using these keys. If the 3468A is in the autoranging mode, pressing either of these keys will cause the 3468A to change range and go into the manual ranging mode.

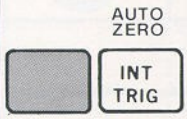
HP-IL COMMANDS

RA Selects autorange mode
R1 – R6 Selects individual manual ranges (see Table 3).

Table 3. 3468A Ranging

Function and Function Code		Range and Range Code					
		R1	R2	R3	R4	R5	R6
DC Volts	F1	0.3 V	3 V	30 V	300 V	*	*
AC Volts	F2	0.3 V	3 V	30 V	300 V	*	*
2-Wire Ohms	F3	300 Ω	3 kΩ	30 kΩ	300 kΩ	3 MΩ	30 MΩ
4-Wire Ohms	F4	300 Ω	3 kΩ	30 kΩ	300 kΩ	3 MΩ	30 MΩ
DC Amps	F5	3 A	*	*	*	*	*
AC Amps	F6	300mA	3A	*	*	*	*

Auto Zero



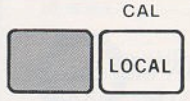
The Auto Zero key allows the user to selectively enable or disable the internal zeroing technique used in the 3468A. Enabling auto zero ensures the user that any offset errors generated internal to the 3468A are continuously nulled with each reading. This provides maximum accuracy. The thermal stability of the measurement environment is the most important factor in deciding whether or not to turn auto zero off. By simply keeping the temperature of the 3468A constant, you can turn auto zero off without significant adverse effects. A change of function or range is always accompanied by an auto zero update, even if auto zero is turned off. The 3468A input circuitry remains in a completely static state with auto zero off. This is useful when making measurements in extremely high impedance circuits where the internal switching transients of the 3468A may affect the reading accuracy.

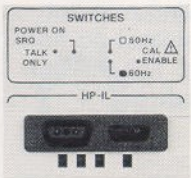
HP-IL COMMANDS

Z0 Turns Auto Zero off
Z1 Turns Auto Zero on

Calibration

The 3468A employs Electronic Calibration to eliminate all internal adjustments. Calibration simply involves connecting a few standards to the 3468A and letting the 3468A store calibration factors in its nonvolatile memory. The front panel keys are used to store these factors during a manual calibration. The 3468A also may be automatically calibrated via HP-IL. Complete information on the calibration procedure may be found in the 3468A Service Manual (Part No. 03468-90001).





The CAL key and the CAL ENABLE switch (on the rear panel) are used only during calibration. **The calibration mode should remain disabled to prevent loss of calibration.**

HP-IL COMMAND

C Calibrate
(see the 3468A Service Manual)

Remote Programming With the HP 41C/CV Handheld Calculator

Introduction

The 3468A is fully programmable via the Hewlett-Packard Interface Loop (HP-IL). It can receive commands to initiate and control measurements, and can send readings to the controller. The controller can also interrogate the status of the 3468A to determine when a measurement has been completed, when an error has occurred, or when the operator has manually flagged the controller from the 3468A front panel.

The 3468A can be combined with the HP 41C/CV handheld calculator and other HP-IL devices, such as printers and cassette tape drives, to provide an automated measurement system. You can measure and analyze performance during a test and then store, print, or plot the results.

The Hewlett-Packard Interface Loop (HP-IL) is a 2-wire serial interface for control of instruments and other devices. HP-IL systems provide easy automation of bench measurements and portable field testing. The controller and all the devices in the system are connected in series, forming a continuous loop communications circuit. Any information (instructions or data) that is transferred among HP-IL devices is passed from one device to the next around the loop (one direction only). If the infomation is not intended for a particular device, that device simply passes the information on to the next device in the loop. When the proper device receives the information, that device responds as directed.

The 3468A may be connected anywhere in the interface loop, which may contain up to 30 devices. When installing or removing the 3468A (or any other device), ALWAYS turn off the calculator first. Then simply disconnect the loop in one place and connect the 3468A at that point. The interface cables must form a continuous loop. All HP-IL connectors are designed to ensure proper orientation and indicate the direction of information transfer.

This discussion of remote programming should be used in conjunction with the operating information provided in Section II. Programs are for the HP 41C/CV handheld calculators. More information on programming and HP-IL may be found in the Model 41C/CV Owner's Handbook and Programming Guide (HP Part No. 00041-90313), and in the Model 82160A HP-IL Module Owner's Manual (HP Part No. 82160-90001). A complete list of 3468A HP-IL commands is provided at the end of this section.

Sending Commands to the 3468A

You can send commands to the 3468A to select the measurement function, range, or resolution; trigger a reading; or interrogate the status of the 3468A. These instructions are sent via the HP-IL command codes listed at the end of this section.

Device Selection (Addressing)

When the 41C/CV calculator is turned on, it will automatically assign an address to each device depending on its position in the loop. The first device in the loop after the calculator (in the direction of information flow) will have an address of "1". The second device will have an address of "2", and so on around the loop. The calculator has an address of "0". This means that the 41C/CV will automatically change the address of the 3468A from 22 (factory preset address) to a number corresponding to the 3468A's location in the loop. (The 3468A must be turned on before the 41C/CV is turned on for the automatic addressing to occur.)

In general, a device must be "SELECTED" by its loop address before any command or information can be sent to it. The following HP-IL control operations define when you need to "SELECT" a device and how the selection is accomplished.

AUTOIO

The AUTOIO mode allows commands unique to a device in the loop to be sent to that device, regardless of which device has been "SELECTED". For many applications, the AUTOIO mode eliminates the need to "SELECT", or address, each device before sending commands to it. As an example, suppose you wanted to put the 3468A into the ac volts mode by sending the "F2" command. If no other device in the loop (such as a printer or tape cassette drive) could respond to the "F2" command, then it would not matter which device was selected when the "F2" command was sent. All devices except the 3468A would ignore the "F2"; only the 3468A would respond to it.

The AUTOIO mode is implemented with the following 41C/CV keystroke sequence.

[XEQ] [ALPHA] AUTOIO [ALPHA]

MANIO

The MANIO mode requires each device to be "SELECTED", or addressed, before a command is sent to that device, regardless of whether any other loop device could respond to that command.

41C/CV Command:

[XEQ] [ALPHA] MANIO [ALPHA]

SELECT

The SELECT command determines which loop device is the selected device, i.e., which device will receive the commands. If the loop is in the AUTOIO mode and if the selected device cannot respond to the transmitted command, the command is passed on around the loop until it reaches a device that can respond to it. The χ register of the 41C/CV must contain the loop address of the device to be selected before SELECT is executed.

41C/CV Command:

[XEQ] [ALPHA] SELECT [ALPHA]

FINDID

The FINDID (FIND IDentity) function searches for a device with a specific identity and determines the loop address of that device. The device identity is placed in the Alpha register of the 41C/CV calculator before FINDID is executed. For the 3468A the identity is: "HP3468A". The decimal address of the device is returned to the χ register of the 41C/CV.

41C/CV Command:

[ALPHA] HP3468A [ALPHA]

[XEQ] [ALPHA] FINDID [ALPHA]

Procedure

The first step in sending a command to the 3468A is to put the 3468A into the REMOTE mode.

41C/CV Command:

[XEQ] [ALPHA] REMOTE [ALPHA]

Then simply decide what you want the 3468A to do and select the appropriate HP-IL command codes. For example, the command code for dc volts is F1, the code for the 3V range is R2, and single trigger is selected by T2. Triggering the 3468A for a single dc volts measurement on the 3V range is accomplished with the following keystrokes on the HP 41C/CV.

1. Put the command codes into the 41C/CV's ALPHA register.

   [ALPHA] F1 R2 T2 [ALPHA]

2. Output the contents of the ALPHA register to the 3468A using the OUTA command:

   [XEQ] [ALPHA] OUTA [ALPHA]

If you had more than one 3468A in the loop or if the loop was in the MANIO mode, the 3468A would need to be SELECTED before the message transmission (see the discussion on "Device Selection (Addressing)" above).

More than one command may be sent to the 3468A at a time. Commands are implemented in the order they are received over HP-IL. Thus, in the above message, the 3468A would go to dc volts first, then go to the 3V range, then would trigger once.

Some Other Examples:

[ALPHA] F3 RA N3 T2 [ALPHA]

- T2 — Single Trigger
- N3 — 3½ Digit Display
- RA — Autorange
- F3 — 2-Wire Ohms

[ALPHA] F2 R3 N5 T1 [ALPHA]

- T1 — Internal Trigger
- N5 — 5½ Digit Display
- R3 — 30V Range
- F2 — AC Volts

Each of these groups of commands would be followed by [XEQ] [ALPHA] OUTA [ALPHA] on the 41C/CV.

You can assign the OUTput Alpha function to a single key on the 41C/CV, eliminating the need to key in [XEQ] [ALPHA] OUTA [ALPHA] each time you send a command. To assign this function to the [Σ+] key, just do this:

ASN

■ [XEQ] [ALPHA] OUTA [ALPHA] [Σ+]

(shift)

Then to output the ALPHA register, just put the 41C/CV into USER mode and press the assigned key:

[USER] [Σ+]

Programming Hints

When more than one command is sent to the 3468A in one string, the commands are executed in the order they arrive. Therefore, it is best to make the trigger statement the last statement in the string, so the 3468A will be set up for the measurement before it is triggered. If you send the command "T2T1", the T1 command is the last one received and will be in effect.

Instructions sent to the 3468A are in the form of 7-bit ASCII characters. All lower case letters, spaces, commas, semicolons and Carriage Return, Line Feed (CR, LF) are ignored. They may be used to format commands for easy readability. All null characters, Form Feed, and tab characters result in a syntax error. All other characters and sequences not explicitly allowed (see the Command Codes) will also result in a syntax error.

Receiving Data From the 3468A

The 3468A has the ability to talk to the HP 41C/CV, giving the results of measurements or status information. We previously saw how to make the voltmeter go to the dc volts function, 3V range, and take one reading. Now we will see how to read back the measured voltage into the 41C/CV. The complete sequence of commands would be:

[XEQ] [ALPHA] REMOTE [ALPHA]
[ALPHA] F1 R2 T2 [ALPHA]
[XEQ] [ALPHA] OUTA [ALPHA]
[XEQ] [ALPHA] IND [ALPHA]

The IND (INput Decimal) command reads the measurement from the selected device and places it into the χ register of the 41C/CV. The reading is then ready to be processed or operated on by the calculator.

Output Format

Readings are sent by the 3468A as 13 bytes in the following formats:

Voltmeter Reading: ±d.dddddE ± d CR LF
Overload: +9.99999E + 9 CR LF

The character "d" represents a single digit. If the 3468A is in the 4½ digit display mode, the last digit returned before the E will be a 0. In the 3½ digit mode, the last two digits will be 0's. CR LF is a standard end-of-line indicator and does not show in the display.

Talk Only Mode

Some applications of the 3468A, such as a simple data logger, may require that the multimeter take readings and output them to some device such as a printer, without the aid of a controller. The 3468A's Talk Only mode allows this type of operation.

Connect the 3468A to an HP Model 82162A Thermal Printer with two HP-IL cables. (The 41C/CV is not to be connected in the loop). The 3468A is set to the Talk Only mode by setting switch number 1, on the rear panel, to the up position. The 82162A printer is set to the Listen Only mode by holding both PRINT and PAPER ADVANCE keys down while turning the printer on.

Measurement data is sent by the multimeter to the printer after each completed reading. Functions and range settings, auto zero, etc., are set from the front panel of the 3468A. The multimeter can be put in the single trigger mode and will output readings only when triggered.

Instrument Status

You can determine the status of the 3468A by interrogating it with the 41C/CV and the INSTAT function. The INSTAT (INput STATus) function causes the 3468A (or the selected device) to output its eight bit Status Byte. A decimal value is placed into the χ register of the calculator. This value is the sum of the values of the bits that are set among the lower six bits. The entire eight bits are also transferred to user Flags 00 through 07 in the 41C/CV calculator, with status byte bit 0 placed in Flag 00, bit 1 in Flag 01, etc. This allows testing of individual bits (Flags).

The INSTAT function is executed by the following 41C/CV command:

[XEQ] [ALPHA] INSTAT [ALPHA]

Status Register and Status Byte

The Status Register in the 3468A continuously monitors seven conditions within the multimeter. The figure below illustrates the Status Register and defines each bit. A bit is set when its corresponding condition occurs.

The Status Byte is an eight bit byte that may be used to determine the current status of the 3468A. The Status Byte is output from the Status Register in response to the INSTAT command.

Bit	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Condition	Power-On Reset	RQS	Cal Error	Front Panel SRQ	Hardware Error	Syntax Error	Invalid Range Function	Data Ready
Value	128	64	32	16	8	4	2	1

Bit 7 of the register will be set only if switch 3 (rear panel of the 3468A) is set to the "UP" position and a power-on reset occurs. It is cleared when the INSTAT message is sent to the 3468A.

Bit 6 of the register will be set (a "1") when the 3468A SRQ Mask has been set for certain bits from bits 0 through 5, and when the corresponding conditions occur.

Bit 6 is cleared when the condition for requesting service no longer exists.

Bit 5 will be true when an attempted calibration fails. The bit is cleared when INSTAT is executed.

Bit 4 is true when the 3468A front panel SRQ key is pressed. The bit is cleared when INSTAT is executed.

Bit 3 is true when a hardware error is detected, such as from the self-test. It is cleared when the Binary Status is read (the B1 command code).

Bit 2 will be true when an invalid command is sent to the 3468A. It is cleared when INSTAT is executed.

Bit 1 is true if an invalid combination of function and range codes are sent to the 3468A, e.g., F2R5. It is cleared when a valid range and function combination is selected.

Bit 0 is set true each time the 3468A completes a reading. This bit is cleared when the reading is read into the 41C/CV with the IND command, when a trigger command is received by the 3468A, or when a program command is executed.

Example: Data Ready

The data ready bit (bit 0 in the status register) of the 3468A allows the calculator to determine when a new measurement is ready. Since the data ready bit is bit 0, it will be placed into the calculator's Flag 00 when the INSTAT command is executed. Therefore, Flag 00 will be the flag tested to see if data is ready. Before trying the following example, make certain that the 3468A is in the Single Trigger mode.

Keystrokes	41C/CV Display	Comments
XEQ ALPHA INSTAT ALPHA	1.0000	Bit 0 is set indicating Data Ready. The value of this bit is "1".
■ FS? 00	YES	The test to see if Flag 00 is set returns a YES answer.
XEQ ALPHA IND ALPHA		The display will show the 3468A reading.
XEQ ALPHA INSTAT ALPHA	0.0000	The data is no longer available. It was read into the calculator. Bit 0 is cleared and INSTAT returns a "0".
■ FS? 00	NO	The Flag test now shows that bit 0 in the status register is clear.

When the 3468A was placed in the Single Trigger mode, it took one reading and stored it internally. When the first INSTAT command was executed, the calculator display showed a "1". This was because bit 0 of the 3468A Status Register was set due to the measurement data being ready. When Flag 00 was tested (FS? 00), it was set and the calculator displayed "YES".

With the IND command, the measurement data was sent to the calculator and, since the 3468A was in the Single Trigger mode, no new measurements were taken. Therefore, no new data became available and bit 0 in the Status Register is clear. This is evident by the second INSTAT command returning a "0" and the test for Flag 00 being "NO".

Example: Front Panel SRQ

The Front Panel SRQ key on the 3468A can be used to flag the 41C/CV calculator. As in the previous example, we'll use the INSTAT and Flag test commands except that we will test Flag 04. Flag 04 represents bit 4 in the Status Register. Before beginning this example, make sure that the 3468A is set to the internal trigger mode.

Keystrokes	41C/CV Display	Comments
XEQ ALPHA INSTAT ALPHA	1.0000	As in the previous example, this indicates Data Ready.
■ FS? 04	NO	Flag 04 (bit 4) is not set.
Now, press the 3468A front panel SRQ key.		
XEQ ALPHA INSTAT ALPHA	17.0000	The display shows 17 for bits 4 (value 16) and 1 (value 1).
■ FS? 04	YES	Flag 04 (bit 4) is set because the SRQ key was pressed.

After the 3468A front panel SRQ key was pressed, bit 4 in the Status Register was set. Consequently, when the INSTAT command was executed, Flag 04 was set.

Example Application Programs

The following programs illustrate some of the measurements you can make with the 3468A in an HP-IL system using the HP 41C/CV handheld calculator. Program listings are from the HP 82162A Thermal Printer. The programs may be entered manually using the 41C/CV keyboard, or may be read in bar code form with the HP 82153A Wand.

Notes

The initialization ("INI68") and building block ("BLOCKS") programs must be entered into the 41C/CV before running any of the other application programs.

Be sure that each program has an END statement as the last line of the program. This will prevent accidental erasure of programs by subsequently entered programs. The END statement is entered on the 41C/CV with the following keystrokes:

GTO
■ RCL • •

If an "END" is not entered, the 41C/CV will automatically insert an ".END." statement. However, the ".END." will not prevent accidental program erasure when another program is entered; only the "END" statement will.

Using the Wand to Read Bar Code Programs

The programs that follow may be easily entered into the 41C/CV by using the HP 82153A Wand to read Bar Codes. Simply plug the wand into the 41C/CV, press the scan switch and scan across each row of bar code. Scan from left to right, starting with row 1 for each program. Each row of bar code also has a notation, such as (1:3) or (4:7), that indicates which program lines are contained in that row of bar code. The GTO • • bar code characters should also be entered at the end of the program to provide an "END" statement. After the complete program is entered, run it by executing XEQ ALPHA (Program Name) ALPHA.

Initialization

The following program locates the 3468A in the loop (finds its address), selects it to receive information, and puts the 3468A into the REMOTE mode. This program should be executed before any other command or program is executed. This initialization program need only be executed once unless a device is turned off or the loop is broken to insert or remove a device. The 82160A HP-IL module must be inserted in the calculator before entering the program.

Initialization Program

41C/CV Keystrokes	41C/CV Display	Listing
PRGM		
■ GTO • •		
■ LBL ALPHA INI68 ALPHA	01 LBL"INI68	01*LBL "INI68"
XEQ ALPHA AUTOIO ALPHA	02 AUTOIO	02 AUTOIO
■ CF 17	03 CF17	03 CF 17
ALPHA HP3468A ALPHA	04 "HP3468A	04 "HP3468A"
XEQ ALPHA FINDID ALPHA	05 FINDID	05 FINDID
XEQ ALPHA SELECT ALPHA	06 SELECT	06 SELECT
XEQ ALPHA REMOTE ALPHA	07 REMOTE	07 REMOTE
■ RTN	08 RTN	08 RTN
GTO • •		09 END
PRGM		

The initialization program has now been entered. If you have not yet connected the 3468A into the loop, do so now. Remember to turn the 41C/CV calculator off before connecting the 3468A. The initialization program will not be lost in the calculator with power turned off.

Note: Line 03 clears flag number 17. This flag controls how the HP-IL interface module uses the standard end-of-line indicator—a Carriage Return (CR) and Line Feed (LF). For most devices, this end-of-line indicator is normally used, and flag 17 should be cleared.

Running the Program

To run the initialization program, press:

XEQ ALPHA INI68 ALPHA

The calculator display will return with the HP-IL address of the 3468A. In addition, the RMT (REMOTE) annunciator will turn on to indicate that the 3468A is ready to accept commands from the calculator. Let's go one step further and assign this program to the calculator Σ+ key. This will make execution of the program easier in the future.

■ ASN ALPHA INI68 ALPHA Σ+

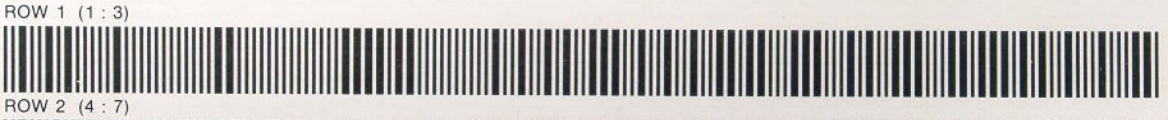
Now, when you need to execute the initialization program, put the calculator in the USER mode and press the Σ+ key.

INI68

HEWLETT PACKARD
3468A PROGRAM

PROGRAM REGISTERS NEEDED: 5

ROW 1 (1 : 3)



ROW 2 (4 : 7)

ROW 3 (7 : 9)

GTO

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Building Block Programming

One approach to program writing uses "Building Block" subprograms to simplify programs. With this approach, you write a mainline program that uses subprograms that already exist. The following program provides seven measurement subprograms and an eighth subprogram that sets up the 3468A for the measurement, triggers the multimeter, and reads the measurement data to the calculator. The seven measurement subprograms are used to specify the type of measurement to be made and then branch to the eighth subprogram.

Program Listing

```
01♦LBL "BLOCKS"
02♦LBL "MVDC"
03 "F1"
04 GTO 00
05♦LBL "MVAC"
06 "F2"
07 GTO 00
08♦LBL "M2OHM"
09 "F3"
10 GTO 00
11♦LBL "M4OHM"
12 "F4"
13 GTO 00
14♦LBL "MADC"
15 "F5"
16 GTO 00
17♦LBL "MAAC"
18 "F6"
19 GTO 00
20♦LBL "MXOHM"
21 "F7"
22♦LBL 00
23 "TRAZ1N4T2"
24 OUTA
25 IND
26 RTN
27 END
```

Measure Volts DC

Measure Volts AC

Measure 2-Wire Ohms

Measure 4-Wire Ohms

Measure Amps DC

Measure Amps AC

Measure Extended Ohms

Label 00. Autorange, Auto Zero on, 4½ Digit Display, Single Trigger, Inputs one reading.

The subprograms, by label and function are:

Label	Function
MVDC	Measure Volts DC. MVDC, along with subprogram 00, sets the 3468A to take one dc voltage measurement.
MVAC	Measure Volts AC. MVAC, along with subprogram 00, sets the 3468A to take one ac voltage measurement.
M2OHM	Measure 2-wire ohms. M2OHM, along with subprogram 00, sets the 3468A to take one 2-wire resistance measurement.
M4OHM	Measure 4-wire ohms. M4OHM, along with subprogram 00, sets the 3468A to take one 4-wire resistance measurement.
MADC	Measure Amps DC. MADC, along with subprogram 00, sets the 3468A to take one dc amps measurement.
MAAC	Measure Amps AC. MAAC, along with subprogram 00, sets the 3468A to take one ac amps measurement.
MXOHM	Measure Extended ohms. MXOHM uses subprogram 00 to set the 3468A to take one extended ohms measurement. See later example.

The next three programs show how these building block subprograms may be used to simplify programming.

BLOCKS

HEWLETT PACKARD
3468A PROGRAM

PROGRAM REGISTERS NEEDED: 18

ROW 1 (1 : 2)

ROW 2 (2 : 5)

ROW 3 (5 : 8)

ROW 4 (8 : 11)

ROW 5 (11 : 14)

ROW 6 (14 : 17)

ROW 7 (17 : 20)

ROW 8 (20 : 23)

ROW 9 (23 : 25)

ROW 10 (26 : 27)

GTO

Temperature Measurements

The TEMP program computes the temperature, in °C, corresponding to the resistance of a thermistor. The program has been designed to work with thermistors exhibiting a 5.000 kohm resistance at 25°C such as a type 44007 (HP part number 0837-0164) or equivalent.

The program was written for 2-wire resistance measurements which provides accurate results if the thermistor is used at a temperature where its resistance is much greater than the resistance of the test leads. For greatest accuracy from a thermistor, a 4-wire resistance measurement should be made. To change from the 2-wire mode to 4-wire mode, change line 15 to read XEQ "M4OHM". This program is useful over a range of −80°C to +150°C.

Program Listing

```
01♦LBL "TEMP"      Label Temperature measurements
02 -6.760961227    Conversion coefficients for
03 STO 01          resistances above 3134 ohms
04 5314.3107       (36°C)
05 STO 02
06 322.807684
07 STO 03
08 -5.952179428    Conversion coefficients for
09 STO 11          resistances equal to or less than
10 4751.384293     3134 ohms (36°C)
11 STO 12
12 303.33182
13 STO 13
14 XEQ "INIT68"    Execute Initialization program
15 XEQ "M2OHM"     Execute measure 2-wire
                   ohms from BLOCKS program
16♦LBL "MEAS"      Tests for resistance above
17 3134            3134 ohms (36°C)
18 ENTER↑
19 TRIGGER
20 IND
21 STO 00
22 X>Y?
23 GTO 35          Get coefficients for
24 RCL 13          temperatures 36°C and above
25 RCL 12
26 RCL 11
27 GTO 36
28♦LBL 35          Get coefficients for
29 RCL 03          temperatures below 36°
30 RCL 02
31 RCL 01
32♦LBL 36          Resistance to temperature
33 RCL 00          conversion
34 LN
35 X<>Y
36 -
37 /
38 X<>Y
39 -
40 STO 00
41 FIX 2
42 "D2"            Display temperature
43 RCL 00
44 ARCL X
45 "┣ DEG C"
46 OUTA
47 GTO "MEAS"
48 END
```

TEMP

HEWLETT PACKARD
3468A PROGRAM

PROGRAM REGISTERS NEEDED: 23

ROW 1 (1 : 2)

ROW 2 (2 : 4)

ROW 3 (4 : 6)

ROW 4 (6 : 8)

ROW 5 (8 : 10)

ROW 6 (10 : 14)

ROW 7 (14 : 15)

ROW 8 (16 : 18)

ROW 9 (19 : 27)

ROW 10 (27 : 36)

ROW 11 (37 : 45)

ROW 12 (45 : 47)

ROW 13 (47 : 48)

GTO

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dBm Measurements

The dBm program is used to calculate power using a 50 ohm impedance as the reference. The dBm equation is:

$$dBm = 10*LOG((X^2/R)/1mW)$$

where X is the measured voltage, R is the reference impedance (50 ohms) and 1 mW is the 0 dBm reference.

The dBm value is displayed on both the 3468A display and the HP Model 41C/CV. Notice the use of subprogram MVAC in line 04.

Program Listing

```
01*LBL "DBM"      — Label dBm Measurements
02 XEQ "INI68"    — Execute Initialization program
03*LBL 00
04 XEQ "MVAC"     — Execute MVAC from
                    BLOCKS program
```

```
05 X↑2
06 50
07 /
08 1 E-3
09 /
10 LOG            — Calculate dBm
11 10
12 *
13 FIX 2
14 RND
15 "D2"
16 ARCL X         — Display dBm on 3468A
17 "├ DBM"
18 OUTA
19 CLA
20 ARCL X         — Display dBm on calculator
21 "├ dBM"
22 AVIEW
23 GTO 00
24  END
```

DBM

HEWLETT PACKARD
3468A PROGRAM

PROGRAM REGISTERS NEEDED: 10

ROW 1 (1 : 2)

ROW 2 (2 : 8)

ROW 3 (8 : 15)

ROW 4 (15 : 20)

ROW 5 (20 : 24)

Extended Ohms

The extended ohms feature of the 3468A is available only via the F7 remote programming command. With extended ohms, the 3468A can be used to measure resistances in excess of 30 Mohms. When in the extended ohms mode, the 3468A goes to the 30 Mohm range, 2-wire mode. An internal resistance of approximately 10 Mohms is placed in parallel (internally) with the input terminals. If this resistance is measured first and then your unknown resistor connected to the input terminals, the parallel combination can be measured.

A calculation can then be performed to determine the approximate value of the unknown resistance. The formula for the calculation is:

$$R_x = \frac{R_i * R_t}{R_i - R_t}$$

R_x is the unknown resistance, R_i is the measured value of the internal 10 Mohm resistor and R_t is the measured value of the parallel combination. The test leads used should be very short, preferably a shielded twisted pair, to minimize noise pickup.

A program to make the necessary measurements, perform the calculations, and display the value of the unknown resistor is given below. Follow the instructions displayed on the HP Model 41C/CV. First it will indicate: OPEN TERMS. This means to remove the test leads from the 3468A. When the message—APPLY RESIST.—appears, connect the unknown resistance to the 3468A. The value of that resistance will be displayed on the calculator. Notice the use of MXOHM subprogram in lines 05 and 11. Continue the program after the prompts with the RUN/STOP key on the 41C/CV.

Program Listing

```
01♦LBL "DXOHM"      — Label – Display Extended Ohms
02 XEQ "INI68"      — Execute Initialization program
03 "OPEN TERMS."    ┐
04 PROMPT           │
05 XEQ "MXOHM"      │ Measure internal 10 Mohm
06 1/X              │ resistor, use MXOHM from
07 STO 00           ┘ BLOCKS program
                      Store inverted value in Reg. 00
08 "APPLY RESIST."  ┐ Measure parallel resistor
09 PROMPT           │ combination
10♦LBL 01           │ Use MXOHM from BLOCKS
11 XEQ "MXOHM"      ┘ program
12 X<=0?            ┐
13 GTO 02           │
14 1/X              │ Calculate value of unknown
15 RCL 00           │ resistor
16 -                │
17 X<=0?            ┘
18 GTO 00           ┐
19 1/X              │
20 1 E6             │ Calculate value of unknown
21 /                │ resistor
22♦LBL 02           │
23 FIX 2            │
24 RND              ┘
25 CLA              ┐
26 ARCL X           │
27 "⊢ MOHM"         │ Display value of resistor
28 AVIEW            │
29 GTO 01           ┘
30♦LBL 00           ┐
31 "OVERLOAD"       │ Display if overload
32 AVIEW            │
33 GTO 01           ┘
34  END
```

DXOHM

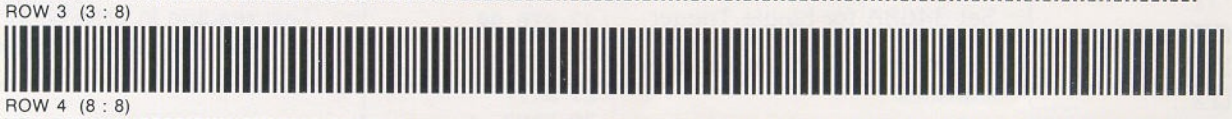
HEWLETT PACKARD
3468A PROGRAM

PROGRAM REGISTERS NEEDED: 16

ROW 1 (1 : 2)

ROW 2 (2 : 3)

ROW 3 (3 : 8)



ROW 4 (8 : 8)

ROW 5 (9 : 14)

ROW 6 (15 : 23)

ROW 7 (24 : 29)

ROW 8 (29 : 33)

ROW 9 (33 : 34)

GTO

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Statistics

The STAT program computes four statistical values for a set of measurements made by the 3468A. The values of mean, standard deviation, minimum and maximum are displayed on the 3468A. This program may be used for any 3468A measurement function. The program does not have provisions for setting the 3468A to your desired measurement function, range, etc. You must either do this manually from the 3468A front panel, or modify line 03 to specify the function, range, etc. Remember that the T2 command must be the last command in the string.

Connect the first device to be measured to the 3468A, then start the program:

XEQ ALPHA STAT ALPHA

The first device will automatically be measured. When the 3468A displays S.TRIG–SRQ, connect the second device to be sampled and press the single trigger (SGL TRIG) key on the 3468A. For each measurement, the 3468A will display the reading and send the result to the calculator. The 3468A will then again display S.TRIG–SRQ. Remove the second device from the 3468A and connect the third device. Again, press the 3468A SGL TRIG key. Continue in this manner until all devices have been tested. At that time, press the 3468A SRQ key (instead of the single trigger key) to begin the analysis of the measurements. First, the 3468A will display the number of samples or devices tested:

N=XXX.0000

Press the 3468A's SRQ key. The 3468A will momentarily display the word "MEAN" and then display the calculated mean value.

MEAN
XXXXXXX

Press SRQ again. The next value displayed is the standard deviation.

STANDARD DEV.
XXXXXXX

Press the SRQ key again to display the minimum value measured.

MINIMUM
XXXXXXX

Press the SRQ key again to display the maximum value measured.

MAXIMUM
XXXXXXX

Pressing the SRQ key again causes the program to prompt with the display:

SRQ=RESTART

This means to press the 3468A SRQ key one more time to restart the statistics program for new data.

Program Listing

```
01♦LBL "STAT"          Label statistics
02 XEQ "INI68"         Execute Initialization program
03 "T2"                Set 3468A for Single Trigger
04 OUTA
05 ΣREG 11             Registers 11–16 are used for
06 CLΣ                 statistics
07 9 E9                Upper and lower measurement
08 STO 00              limits
09 CHS
10 STO 01
11 CLX
12♦LBL 00              Display message and set
13 "D2S. TRIG-SRQ"     3468A to local mode
14 OUTA
15 LOCAL
16♦LBL 01
17 INSTAT              Input status byte
18 FS? 04              If flag 4 (SRQ) is set, go to
19 GTO 02              LBL 02 (line 34)
20 FC? 00              If data is ready (flag 00 clear)
21 GTO 01              proceed to line 22, if not, go
                       to LBL 01 (line 16)
22 IND                 Input reading and increment
23 Σ+                  Reg 11
24 RCL 00              Test reading in case of
25 LASTX               exceeding upper and lower
26 X<Y?                limits
27 STO 00
28 RCL 01
29 X<>Y
30 X>Y?
31 STO 01
32 R↑                  Roll up and store reading
33 GTO 00              Go to LBL 00 (line 12) for
                       next reading
34♦LBL 02              SRQ key pressed, all samples
                       taken
35 "D2N="              Display number of samples
36 ARCL 16             (lines 67–73)
37 XEQ 04
38 "D2MEAN"            Calculate and display mean
39 OUTA                value (lines 65–76)
40 "D2"
41 MEAN
42 ARCL X
43 XEQ 03
```

```
44 "D2STANDARD DEV."
45 OUTA
46 "D2"
47 SDEV
48 ARCL X
49 XEQ 03
50 "D2MINIMUM"
51 OUTA
52 "D2"
53 ARCL 00
54 XEQ 03
55 "D2MAXIMUM"
56 OUTA
57 "D2"
58 ARCL 01
59 XEQ 03
60 "D2SRQ=RESTART"
61 XEQ 04
62 FS? 04
63 GTO "STAT"
64 GTO 00
65♦LBL 03
66 PSE
67♦LBL 04
68 OUTA
69 LOCAL
70♦LBL 05
71 INSTAT
72 FS? 04
73 RTN
74 FS? 00
75 RTN
76 GTO 05
77  END
```

Calculate and display standard deviation (lines 65 – 76)

Calculate and display minimum value (lines 65 – 76)

Calculate and display maximum value (lines 65 – 76)

If SRQ key pressed, start over (lines 67 – 76)

Pause (line 66)
Output message (line 68)
Enable 3468A keyboard (line 69)

Input status (line 71)
SRQ flag set test (line 72)
Data Ready flag test (line 74)

STAT

HEWLETT PACKARD
3468A PROGRAM

PROGRAM REGISTERS NEEDED: 32

ROW 1 (1 : 2)

ROW 2 (2 : 7)

ROW 3 (8 : 13)

ROW 4 (13 : 17)

ROW 5 (18 : 25)

ROW 6 (26 : 35)

ROW 7 (35 : 38)

ROW 8 (38 : 44)

ROW 9 (44 : 44)

ROW 10 (44 : 49)

ROW 11 (50 : 52)

ROW 12 (52 : 55)

ROW 13 (55 : 59)

ROW 14 (59 : 60)

ROW 15 (60 : 63)

ROW 16 (64 : 72)

ROW 17 (72 : 77)

GTO

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Data Logger

The following data logger program (LOGGER) illustrates the power and flexibility of an HP-IL system. The program takes 10 sets of 10 readings each, for a total of 100 readings, and stores them on a cassette tape for future reference. The program can easily be enhanced by adding a linearization routine between lines 15 and 16. An example of linearization is the previous program where the resistance of a thermistor was converted to a temperature. In this way, temperature measurements rather than resistance measurements are stored on the tape.

The program READ demonstrates how easily data can be read from the cassette tape and listed on a printer. Again, this program can be enhanced by adding a routine to plot the data on the printer. Of course, the data can also be printed or plotted as the measurements are being taken in the LOGGER program.

Running the LOGGER Program

Make certain that the interface loop connections have been made between the 3468A multimeter, 41C/CV calculator, 82161A digital cassette drive, and the 82162A printer. Turn all of the devices on.

Before data can be stored on the cassette tape, the tape must be initialized. This is done by executing the NEWM command (NEW Medium). Refer to the HP-IL Owners Manual.

[XEQ] [ALPHA] NEWM [ALPHA] 100

Line 03 executes the MVAC subprogram. This can be changed to suit your needs. Deleting the line entirely gives you the freedom of setting the 3468A manually as often as needed. When the device to be tested has been connected to the 3468A input terminals and you are ready to begin, execute:

[XEQ] [ALPHA] LOGGER [ALPHA]

How the Program Works

Space for storing the 100 readings must be allocated on the cassette tape. This space (or file) is created and given the name DATA in lines 04, 05, and 06. Lines 07 and 08 are used to return to the beginning of the DATA file on the cassette for data storage.

Register 00 is used as a loop counter to take 10 sets of readings. The value 1.010 is STOred into Register 00 (lines 09, 10) and is incremented and tested in line 22.

Register 01 (lines 12, 13) also acts as a loop counter, but counts 10 readings per set (Register 00). The value 11.020 stored into register 01 specifies registers 11 through 20 as temporary storage registers for the measurement data. Line 15 triggers the 3468A and line 16 inputs the results. Line 17 stores the data in the register pointed to by Register 01. Register 01 is incremented after each reading to point to the next empty register in line 18.

Register 01 is also tested in line 18. Remember that program line 12 specified Register 20 as the last register to be used. If Register 01 points to register 21, then the program prepares to store the 10 readings on the cassette. Line 20 calls out register 11 through 20 as data storage registers. The WRTRX command (line 21) writes the data from the storage registers to the cassette tape.

Register 00 is tested in line 22 to see if 10 sets of 10 readings each have been made. If not, the program loops back (line 23) to label 01 (line 11). When 10 sets of measurements have been made, the program ends.

Program Listing

```
01♦LBL "LOGGER"      Label Logger
02 XEQ "INI68"       Execute Initialize program
03 XEQ "MVAC"
04 "DATA"
05 100
06 CREATE            Set up DATA file on cassette tape
07 0
08 SEEKR
09 1.010             Set up loop counter for 10 sets of readings
10 STO 00
11♦LBL 01
12 11.020            Set up register 11 to 20 to store readings
13 STO 01
14♦LBL 02
15 TRIGGER
16 IND               Trigger the 3468A, input reading and store
17 STO IND 01
18 ISG 01            If 10 readings taken go to line 20, else go to line 14
19 GTO 02
20 11.020            Store 10 readings on cassette tape
21 WRTRX
22 ISG 00
23 GTO 01            End if 10 sets of readings have been taken, also go to line 11
24  END

01♦LBL "READ"        Label READ
02 "DATA"
03 0
04 SEEKR             Find beginning of DATA file on cassette tape
05 1.010
06 STO 00            Set up loop counter for 10 sets of readings
07♦LBL 01
08 11.020
09 READRX            Read one set of 10 readings
10 11.020
11 PRREGX            Print set
12 ISG 00
13 GTO 01            End if 10 sets have been read, else go to line 07
14  END
```

LOGGER

HEWLETT PACKARD
3468A PROGRAM

PROGRAM REGISTERS NEEDED: 11

ROW 1 (1 : 2)

ROW 2 (2 : 4)

ROW 3 (4 : 9)

ROW 4 (9 : 15)

ROW 5 (15 : 20)

ROW 6 (20 : 24)

GTO • •

READ

HEWLETT PACKARD
3468A PROGRAM

PROGRAM REGISTERS NEEDED: 7

ROW 1 (1 : 2)

ROW 2 (3 : 8)

ROW 3 (8 : 11)

ROW 4 (12 : 14)

GTO • •

3468A HP-IL Command Codes

(The command codes are also found on the under side of the 3468A)

Function Code		Range Codes						
		R1	R2	R3	R4	R5	R6	RA Autorange
DC Volts	F1	.3 V	3 V	30 V	300 V	*	*	
AC Volts	F2	.3 V	3 V	30 V	300 V	*	*	
2-Wire Ohms	F3	300 Ω	3 kΩ	30 kΩ	300 kΩ	3 MΩ	30 MΩ	
4-Wire Ohms	F4	300 Ω	3 kΩ	30 kΩ	300 kΩ	3 MΩ	30 MΩ	
DC Amps	F5	3 A	*	*	*	*	*	
AC Amps	F6	300 mA	3 A	*	*	*	*	
Extended Ohms	F7	(default range)	*	*	*	*		

*Indicates an invalid combination of Function and Range codes.

Other Program Codes:

Function	Qualifier	Description	Example
N	3,4,5	Selects the number of digits of display	N3 selects the 3½ digit display mode
T	1,2	Trigger Mode: Internal, Single	T1 selects internal trigger, T2 selects single
Z	0,1	Auto Zero mode: off, on	Z0 turns Auto Zero off
C		Calibrate (see 3468A Service Manual)	
D	1,2	Display mode: Normal, Text	D2text displays the message "text" on the 3468A display
Mbb	0 to 77 (octal)	Set SRQ mask to octal value bb. This sets the lower 6 bits of mask. The Mbb command is executed as sent. Therefore, if the second "b" is not sent, bits 3 to 6 are set by the "b" that is received.	M01 sets the 3468A for data ready SRQ
B	1	Binary Status. The 3468A, if it is addressed to talk immediately after receiving the B1 command, will output its five binary status bytes. This command also clears the error register (byte 4). The meaning of the bytes is as follows: Byte 1: Function, Range, Number of Digits Octal value of bits 7,6,5 = 1 DC Volts = 2 AC Volts = 3 2-W Ohms = 4 4-W Ohms = 5 DC Amps = 6 AC Amps = 7 Extended Ohms Octal value of bits 4,3,2 = 1 Range R1 = 2 R2 = 3 R3 = 4 R4 = 5 R5 = 6 R6 Octal value of bits 1,0 = 0 invalid = 1 5½ digit = 2 4½ digit = 3 3½ digit	

Function	Qualifier	Description	Example
B	1	Byte 2: Status Bits Bits 7,6,5 are not used (always 0) Bit 4: "1" is calibration ram enabled Bit 3: "1" is line frequency switch set to 50 Hz position. "0" is 60 Hz position. Bit 2: "1" is auto zero on, "0" is auto zero off Bit 1: "1" is autorange on Bit 0: "1" is internal trigger, "0" is single trigger Byte 3: SRQ Mask Bit 7: "1" SRQ if power-on or test/reset set by rear panel switch #3 Bit 6: not used (always "0") Bit 5: "1" SRQ if calibration procedure failed Bit 4: "1" SRQ if keyboard SRQ is pressed Bit 3: "1" SRQ if hardware error occurs Bit 2: "1" SRQ if syntax error occurs Bit 1: "1" SRQ if invalid syntax error occurs Bit 0: SRQ as each reading becomes available Byte 4: Error Information Bits 7,6,5,4 are not used (always "0") Bit 3: "1" A/D error detected Bit 2: "1" Microprocessor ROM error Bit 1: "1" Microprocessor RAM error Bit 0: "1" Calibration RAM error, the calibration of the 3468A is suspect Byte 5: A/D Converter DAC Value This byte will contain a value between 0 and 63 (decimal). This represents the setting of the internal Digital to Analog Converter (DAC), and is primarily for diagnostic purposes.	

Specifications and Accessories

DC VOLTAGE

Input Characteristics:

Range	Maximum Reading (5½ digit)	Resolution		
		5½ digit	4½ digit	3½ digit
.3 V	±.301000 V	1 μV	10 μV	100 μV
3 V	±3.01000 V	10 μV	100 μV	1 mV
30 V	±30.1000 V	100 μV	1 mV	10 mV
300 V	±301.000 V	1 mV	10 mV	100 mV

Input Resistance:
.3 V, 3 V ranges: $>10^{10}\Omega$
30 V, 300 V ranges: 10 MΩ ± 1%

Maximum Input Voltage: (non-destructive)
Hi to Lo: 301 Vrms or 450 V peak
Hi or Lo to Earth Ground: ±500 V peak

Measurement Accuracy:
±(% of reading + number of counts)
Auto zero ON.

5½ DIGIT MODE:

Range	T_{Cal}* ±1°C	T_{Cal}* ±5°C	
	24 Hour	90 Day	1 Year
.3 V	0.005 + 4	0.009 + 5	0.02 + 5
3 V	0.0035 + 2	0.007 + 2	0.018 + 2
30 V	0.005 + 3	0.009 + 3	0.02 + 3
300 V	0.0055 + 2	0.009 + 2	0.02 + 2

4½ AND 3½ DIGIT MODE:
Accuracy is the same as 5½ digit mode for % of reading; use 1 count for number of counts.

*T_{Cal} is the temperature of the environment where the 3468A was calibrated. Calibration should be performed with the temperature of the environment between 20°C and 30°C.

Auto Zero Off:
(5½ digits) For a stable environment (±1°C) for <24 hrs., add 11 counts to accuracy specification for .3 V and 30 V ranges, 3 counts for 3 V and 300 V ranges.

Temperature Coefficient:
0° to 55°C, 5½ digits, auto zero ON.
±(% of reading + number of counts)/°C

Range	Temperature Coefficient
.3 V, 30 V	0.0008 + .5
3 V, 300 V	0.0007 + .05

Noise Rejection:
In dB, with 1 kΩ imbalance in Lo lead. AC rejection for 50, 60 Hz ±0.1%. Auto zero ON.

Display	AC NMR	AC ECMR	DC CMR
5½ digits	80	150	140
4½ digits	59	130	140
3½ digits	0	70	140

Reading Rates: (readings/sec)

MAXIMUM READING RATE WITH HP 85A:

Line Frequency	Auto Zero	Resolution		
		3½ digits	4½ digits	5½ digits
60 Hz	Off	32	21	3.7
	On	25	13.4	2
50 Hz	Off	32	19	3.1
	On	25	12	1.7

MAXIMUM READING RATE WITH 41CV:
2 readings/sec
First reading is correct when triggered coincident with step input.

Display Rate: (readings/sec)

	5½ Digits	4½ or 3½ Digits
Auto Zero Off	4	4
Auto Zero On	2	4

For 50 or 60 Hz operation

3468A Accessories

Accessory Number	Description
10023A	Temperature Probe
11096B	RF Probe
34111A	High Voltage Probe
34118A	Test Lead Kit
34110A	Soft Vinyl Carrying/Operating Case
82167A	HP-IL Cable (0.5 m)
Option 910	Additional Operator's Manual (03468-90000) and Service Manual (03468-90001)

RESISTANCE (2-wire Ω, 4-wire Ω)

Input Characteristics:

Range	Maximum Reading (5½ digit)	Resolution		
		5½ digit	4½ digit	3½ digit
300 Ω	301.000 Ω	1 mΩ	10 mΩ	100 mΩ
3 kΩ	3.01000 kΩ	10 mΩ	100 mΩ	1 Ω
30 kΩ	30.1000 kΩ	100 mΩ	1 Ω	10 Ω
300 kΩ	301.000 kΩ	1 Ω	10 Ω	100 Ω
3 MΩ	3.01000 MΩ	10 Ω	100 Ω	1 kΩ
30 MΩ	30.1000 MΩ	100 Ω	1 kΩ	10 kΩ

Input Protection: (non-destructive)
Hi source to Lo source: ±350 V peak
Hi sense to Lo sense: ±350 V peak
Hi or Lo to Earth Ground: ±500 V peak

Measurement Accuracy:

±(% of reading + number of counts)
Auto zero ON. 5½ digit display. 4-wire ohms.

Range	T_{Cal} ±1°C	T_{Cal} ±5°C	
	24 Hour	90 Day	1 Year
300 Ω	0.004 + 4	.012 + 5	0.017 + 5
3 kΩ–300 kΩ	0.004 + 2	.011 + 2	0.016 + 2
3 MΩ	0.005 + 2	.011 + 2	0.016 + 2
30 MΩ	0.036 + 2	.066 + 2	0.078 + 2

2-WIRE OHMS ACCURACY: Same as 4-wire ohms, except add a maximum of 100 mΩ offset

Auto Zero Off:

(5½ digits) For a stable environment (±1°C) for <24 hrs., add 11 counts to accuracy specification for 300 Ω range, 3 counts for 3 kΩ through 300 kΩ ranges, 8 counts for 3 MΩ range, and 33 counts for 30 MΩ range.

Temperature Coefficient:

0° to 55°C, 5½ digits, auto zero ON.
±(% of reading + number of counts)/°C

Range	Temperature Coefficient
300 Ω	0.0009 + 0.5
3 kΩ–300 kΩ	0.0009 + 0.05
3 MΩ	0.0021 + 0.05
30 MΩ	0.021 + 0.05

Current Through Unknown:

Range	300 Ω	3 kΩ	30 kΩ	300 kΩ	3 MΩ	30 MΩ
Current	1 mA	1 mA	100 μA	10 μA	1 μA	100 nA

Maximum Open Circuit Voltage: 6.5 V

Maximum Reading Rates:

Same as dc volts except for 3 MΩ and 30 MΩ ranges. For 3 MΩ range, add 20 ms; for 30 MΩ range, add 200 ms per reading.

AC VOLTAGE (true rms responding)

Input Characteristics:

Range	Maximum Reading (5½ Digit)	Resolution		
		5½ Digit	4½ Digit	3½ Digit
.3 V	.301000 V	1 μV	10 μV	100 μV
3 V	3.01000 V	10 μV	100 μV	1 mV
30 V	30.1000 V	100 μV	1 mV	10 mV
300 V	301.000 V	1 mV	10 mV	100 mV

Input Impedance: 1 MΩ ± 1% shunted by <60 pF

Maximum Input Voltage: (non-destructive)
Hi to Lo: 301 Vrms or 450 V peak
Hi or Lo to Earth Ground: ±500 V peak

Measurement Accuracy:

±(% of reading + number of counts)
Auto zero ON. 5½ digit display. Accuracy is specified for sinewave inputs only, >10% of full scale.

1 Year, T_{Cal} ±5°C.

Frequency	Ranges		
	.3 V	3 V, 30 V	300 V
20–50 Hz	1.14 + 163	1.14 + 102	1.18 + 102
50–100 Hz	0.46 + 163	0.46 + 103	0.5 + 102
100 Hz–20 kHz	0.29 + 163	0.26 + 102	0.33 + 102
20–50 kHz	0.56 + 247	0.41 + 180	0.55 + 180
50–100 kHz	1.74 + 882	1.05 + 825	1.26 + 825
100 k–300 kHz	10.1 + 3720 (30 V range only)		

Auto Zero Off:

(5½ digits) For a stable environment (±1°C) for <24 hrs., add 10 counts to accuracy specification for all ranges.

Temperature Coefficient:

0° to 55°C, 5½ digits, auto zero ON.
For frequencies <20 kHz, ±(0.016% of reading + 10 counts)/°C
For frequencies <20 kHz, ±(0.04% of reading + 10 counts)/°C

Crest Factor:

>4:1 at full scale

Common Mode Rejection:

With 1 kΩ imbalance in Lo lead, >70 dB, dc to 60 Hz

Maximum Reading Rates:

First reading is correct within 70 counts of final value when triggered coincident with step input. Add 0.6 seconds for each range change.

REMOTE CONTROL AND DISPLAY RATE:
For 50 or 60 Hz operation, auto zero ON or OFF.
3½ or 4½ digits: 1.4 readings/sec
5½ digits: 1.0 readings/sec

DC CURRENT

Input Characteristics:

Range	Maximum Reading (5½ digit)	Resolution		
		5½ digit	4½ digit	3½ digit
3A	±3.01000 A	10 μA	100 μA	1 mA

Maximum Input: (non-destructive)
3A from <250 V source; fuse protected

Measurement Accuracy:
±(% of reading + number of counts)
Auto zero ON. 5½ digit display.

Range	T_{Cal} ±5°C	
	90 Days	1 Year
3 A, <1 A input	0.14 + 6	0.17 + 6
3 A, >1 A input	1.0 + 30	1.0 + 30

Auto Zero Off:
(5½ digits) For a stable environment (±1°C) for <24 hrs., add 11 counts to accuracy specification.

Temperature Coefficient:
0° to 55°C, 5½ digits, auto zero ON.
±(0.012 of reading + 0.5 counts)/°C

Maximum Burden at Full Scale:
1 V

Maximum Reading Rates:
Same as dc volts

AC CURRENT (true rms responding)

Input Characteristics:

Range	Maximum Reading (5½ digit)	Resolution		
		5½ digit	4½ digit	3½ digit
.3 A	.301000 A	1 μA	10 μA	100 μA
3 A	3.01000 A	10 μA	100 μA	1 mA

Maximum Input: (non-destructive)
3A from <250 V source; fuse protected

Measurement Accuracy:
±(% of reading + number of counts)
Auto zero ON. 5½ digit display. Accuracy specified for sinewave inputs only, >10% of full scale.

1 Year, T_{Cal} ±5°C

Frequency	Ranges	
	.3 A	3 A
20–50 Hz	1.77 + 163	2.5 + 163
50–1 kHz	1.1 + 163	1.8 + 163
1 k–10 kHz	1.0 + 163	1.7 + 163
10 k–20 kHz	1.14 + 163	1.84 + 163

Auto Zero Off:
(5½ digits) For a stable environment (±1°C) for <24 hrs., add 10 counts to accuracy specification.

Temperature Coefficient:
0° to 55°C, 5½ digits, auto zero ON.
±(0.021% of reading + 10 counts)/°C

Maximum Burden at Full Scale:
1 V

Crest Factor:
>4:1 at full scale

Maximum Reading Rates:
Same as ac volts

GENERAL INFORMATION

Operating Temperature: 0 to 55°C

Humidity Range: 95% R.H., 0 to 40°C

Storage Temperature: −40°C to 75°C; except for battery option, −40°C to +65°C

Warm-up Time: 1 hr. to meet all specifications

Integration Time:

Number of Digits	Line Frequency	
	50 Hz	60 Hz
5½	200 ms	166.7 ms
4½	20 ms	16.67 ms
3½	2 ms	1.667 ms

Power: AC Line 48–440 Hz; 86–250 V, (see configuration)

Battery: (Option 001) Rechargeable lead-acid; minimum continuous operation for 5 hours at 25°C; recharge time is 16 hours with 3468A off and 36 hours with 3468A on.

Maximum Power: 13 VA

Size: 98.4 mm H x 238.1 mm W x 276.2 mm D (3.88 in H x 9.38 in W x 10.88 in D)

Weight:
3468 — 2,1 kg (4.63 lbs.)
3468A with Option 001 — 3,1 kg (6.83 lbs.)

3468A HP-IL Command Code Quick Reference Guide

(The command codes are also found on the under side of the 3468A.)

Function Code		Range Codes						
		R1	R2	R3	R4	R5	R6	RA Autorange
DC Volts	F1	.3 V	3 V	30 V	300 V	*	*	
AC Volts	F2	.3 V	3 V	30 V	300 V	*	*	
2-Wire Ohms	F3	300 Ω	3 kΩ	30 kΩ	300 kΩ	3 MΩ	30 MΩ	
4-Wire Ohms	F4	300 Ω	3 kΩ	30 kΩ	300 kΩ	3 MΩ	30 MΩ	
DC Amps	F5	3 A	*	*	*	*	*	
AC Amps	F6	300 mA	3 A	*	*	*	*	
Extended Ohms	F7	(default range) 10 MΩ/Rx	*	*	*	*	*	

*Indicates an invalid combination of Function and Range codes.

Other Program Codes:

Function	Qualifier	Description	Example
N	3,4,5	Selects the number of digits of display	N3 selects the 3½ digit display mode
T	1,2	Trigger Mode: Internal, Single	T1 selects internal trigger, T2 selects single
Z	0,1	Auto Zero mode: off, on	Z0 turns Auto Zero off
C		Calibrate (see 3468A Service Manual)	
D	1,2	Display mode: Normal, Text	D2text displays the message "text" on the 3468A display
Mbb	0 to 77 (octal)	Set SRQ mask to octal value bb. This sets the lower 6 bits of mask. The Mbb command is executed as sent. Therefore, if the second "b" is not sent, bits 3 to 6 are set by the "b" that is received.	M01 sets the 3468A for data ready SRQ
B	1	Binary Status	

HEWLETT PACKARD

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